

Stress Behavior and Characteristics of Knee Brace in Steel Box-girder Bridges

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ABSTRACT

Knee brace in steel-box-girder bridges is generally installed between cross-beam and box-girder as a stiffener without structural evaluation for its safety and stiffened efficiency. The installation of the knee brace aims to carry out rigid connection between the cross-beam and the box-girder, to relieve stress concentration generated and to prevent lateral deformation at connection. However, research on the stiffening capacity and the efficiency of the knee brace is insufficient. It is necessary for design improvement of the steel box girder bridges to determine on the stiffening capacity and the efficiency of the knee brace as the stiffener by using parametric study.

Finite element analyses are performed to investigate structural behavior of knee brace. Stress flow and level of cross-beam, diaphragm and web are evaluated by parametric analysis with the installation of the knee brace and the depth ratio of cross-beam/steel box girder. It is seen from comparison of analytical results that the knee brace installed in the cross-beam of the steel box-girders bridges is not efficient as the structural stiffener in order to stress relief and stiffened effect.

1. INTRODUCTION

In steel box-girder bridges, cross-beams and stringers are components of floor system, whose functions are resisted against dead or live loads and distributed them toward steel box-girders. Knee brace is generally installed at connection between the cross-beam and the main steel box-girder as a structural stiffener and a component of the floor system. [1] In the steel box-girder bridge, the knee brace is attached with triangle shape between lower flange of the cross-beam and web of the steel box-girder, and additionally covered by a flange plate as shown in figure 1.

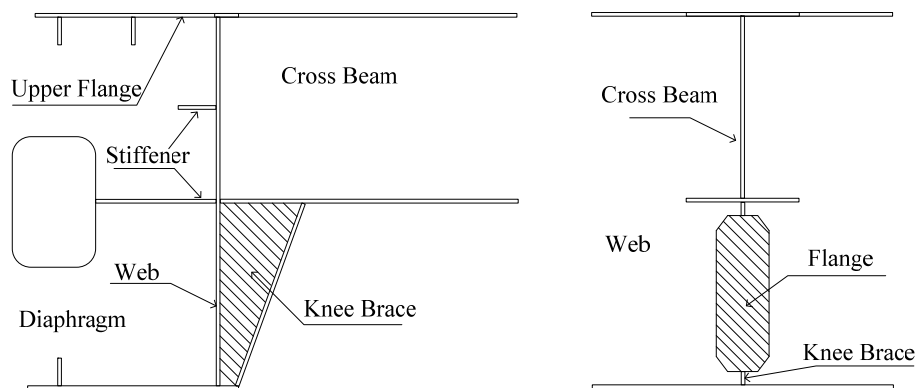


Figure 1. Knee brace and details of connection between cross-beam and steel box-girder

Installation of the knee brace have been aimed at rigidly connecting between cross-beam and steel box-girder, relieving stress concentration generated at joint and preventing lateral deformation of main-girders. However, research on the stiffened capacity and the efficiency of the knee brace is insufficient. Furthermore, the knee brace is reported as an un-merited structural detail in accordance with fatigue life, weld detail and etc. For design improvement of the steel box-girder bridge in terms of structural safety and economics, determination of structural efficiency and stiffened effect of the knee brace is required. [2]

Aim of this study is to investigate stiffened efficiency of knee brace as a stiffener member by analytical approaches. The parametric numerical analyses with installation of the knee brace, depth ratio of cross-beam/steel box-girder and cross-beam length are achieved. Stress flow and level of the knee brace as well as web, diaphragm and cross beam are presented by comparing the analytical results.

2. NUMERICAL ANALYSIS

2.1 FE Modeling

Finite element analysis is performed to investigate stiffened efficiency of a knee brace as a connection member of cross-beam and steel box girder. ABAQUS/Standard FE program is employed in the numerical analysis. [3] In the analysis, a middle part of steel box-girder bridge with length of 5m is implemented as the FE modeling. To consider a concrete deck and its weight, a couple of concrete deck and steel box girder is modeled as shown in figure 2. Eight node cubic element (C3D8R) and four node shell element (S4R) are respectively employed in the concrete deck and the steel box-girder FE modeling. Finite deformation theory is used in the numerical analysis to describe the geometric non-linearity. Coupled constraint technique of ABAQUS is involved to consider the composite effect by stud between the concrete deck and the steel box-girder.

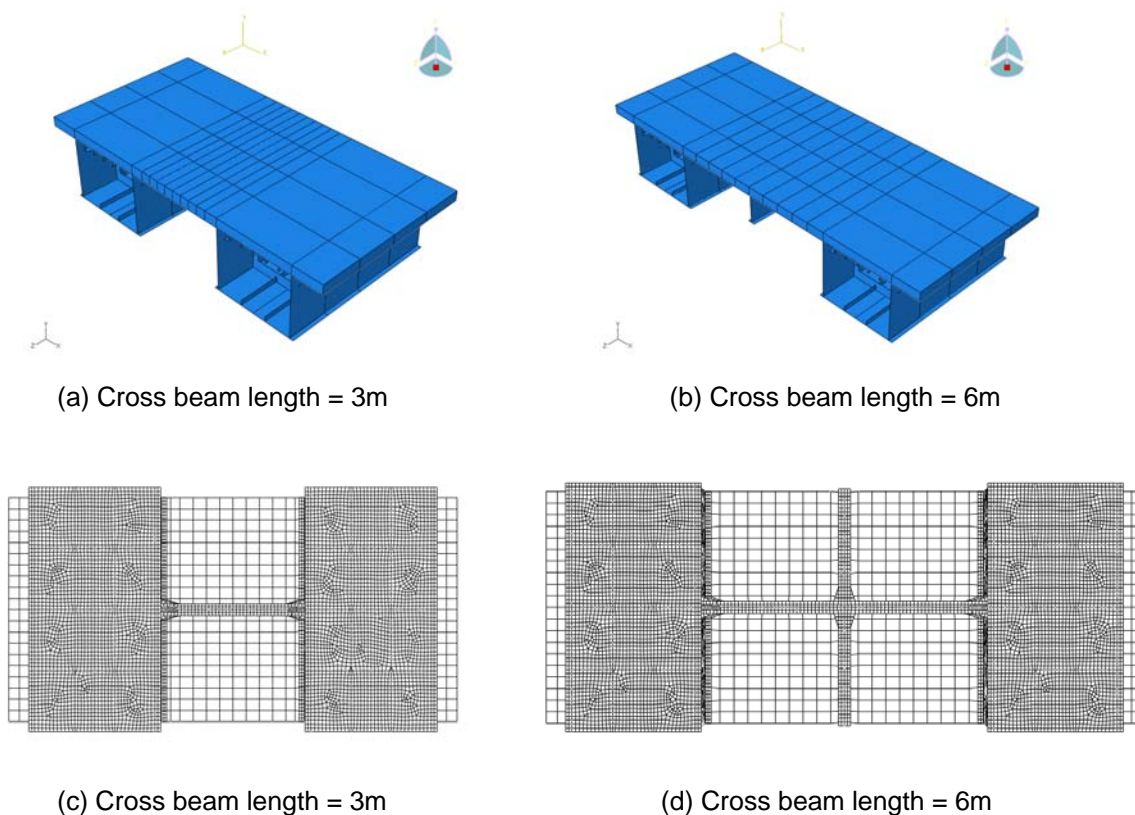


Figure 2. FE modeling of steel box-girder bridge.

2.2 Analytical Condition

In numerical analysis, model for analysis is mainly classified by cross-beam length, 3m or 6m, as shown in figure 2. In the case of steel box-girder bridge with 6m length cross beam, stringer is installed to distribute service load as shown in figure 2(d). Geometrics of steel box-girder sections are shown in figure 3(a), (b). Conservatively, SM490 steel is used at main members, flanges and webs of the box girders, and SM400 steel is used at the other members. Mechanical properties of SM400, SM490 and concrete present at table 2. Model for analysis is classified by length of cross beam and whether knee brace is installed or not as shown in table 1. Where parameter of B_w/H is a depth ratio of cross-beam/box-girder.

Table 1. Classification of steel box girder model in analysis

model	Length of cross-beam(mm)	Knee-brace	B_w/H	Cross Beam	Height of cross beam (mm)	Height of box girder (mm)
CB-3-O-0.4	3,000	Installed	0.4	Not installed	800	2,000
CB-3-X-0.4	3,000	Not installed	0.4	Not installed	800	2,000
CB-3-O-0.5	3,000	Installed	0.5	Not installed	1,000	2,000
CB-3-X-0.5	3,000	Not installed	0.5	Not installed	1,000	2,000
CB-3-O-0.6	3,000	Installed	0.6	Not installed	1,200	2,000
CB-3-X-0.6	3,000	Not installed	0.6	Not installed	1,200	2,000
CB-3-O-0.7	3,000	Installed	0.7	Not installed	1,400	2,000
CB-3-X-0.7	3,000	Not installed	0.7	Not installed	1,400	2,000
CB-6-O-0.4	6,000	Installed	0.4	Installed	800	2,000
CB-6-X-0.4	6,000	Not installed	0.4	Installed	800	2,000
CB-6-O-0.5	6,000	Installed	0.5	Installed	1,000	2,000
CB-6-X-0.5	6,000	Not installed	0.5	Installed	1,000	2,000
CB-6-O-0.6	6,000	Installed	0.6	Installed	1,200	2,000
CB-6-X-0.6	6,000	Not installed	0.6	Installed	1,200	2,000
CB-6-O-0.7	6,000	Installed	0.7	Installed	1,400	2,000
CB-6-X-0.7	6,000	Not installed	0.7	Installed	1,400	2,000

Table 2. Mechanical properties of material used

Steel or concrete grade	Elastic modulus (GPa)	Yield strength (MPa)	Tensile strength (MPa)	Possion ratio	Density (kgf/m ³)
SM400	205	240	400	0.30	7,850
SM490	205	320	490	0.30	7,850
Concrete used in deck	27	27	-	0.16	2,500

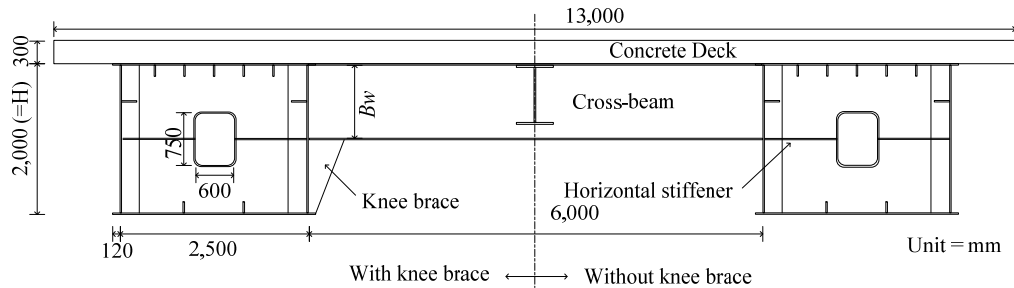
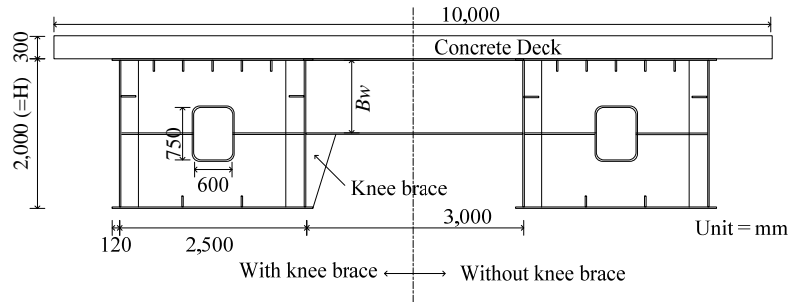


Figure 4. Load condition of analysis models

3. ANALYTICAL RESULTS AND DISCUSSION

3.1 Stress Flow

Parametric analyses for installation of knee-brace and cross-beam length are achieved by using ABAQUS FE program. To observe stress flow of connection between cross-beam and steel box-girder, maximum principal stress is plotted based on the analytical results as show in figure 5. Figure 5 shows a sectional stress flow of analysis models (CB-3-X-0.5, CB-3-O-0.5, CB-6-X-0.5, and CB-6-O-0.5).

In all analysis models, stresses by service load are mainly distributed at web and low-flange of cross beam near joint. However, stress flow of web of box-girder and knee-brace is insignificant. Furthermore, regardless of installation of the knee-brace, analysis models show the similar stress flow in the cross beam and the web. It is, therefore, seen from comparing the stress flow of analysis models that the knee brace is not efficient as a stiffener to relieve stress concentration in connection between the cross-beam and the steel box-girder.

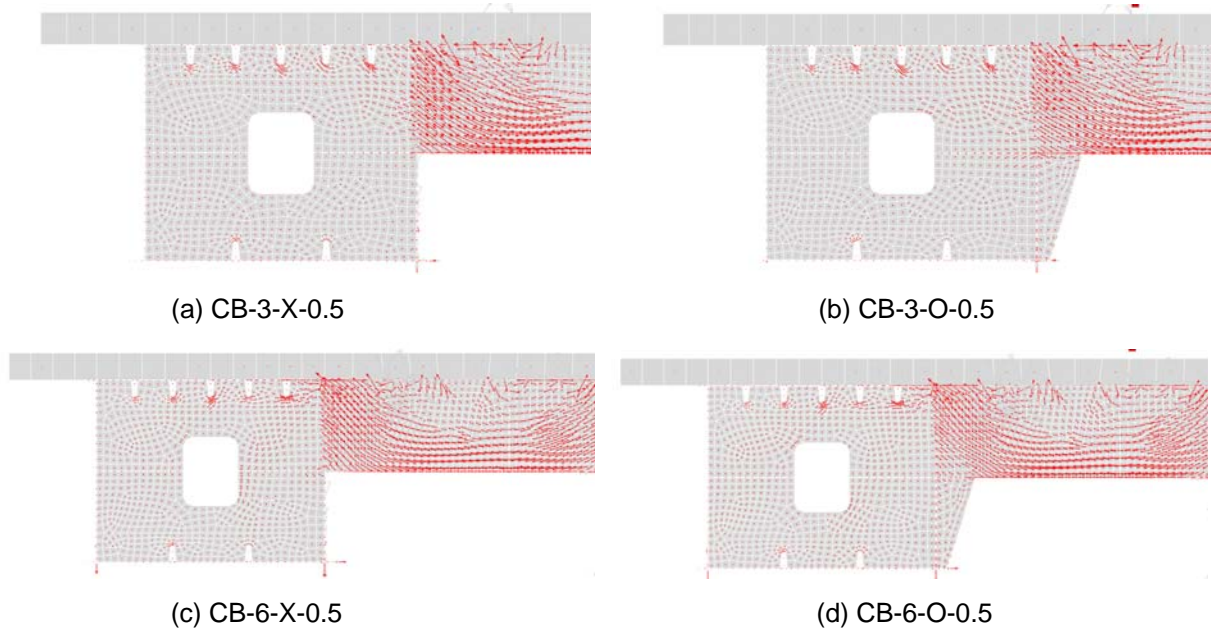


Figure 5. Stress flow of analysis models

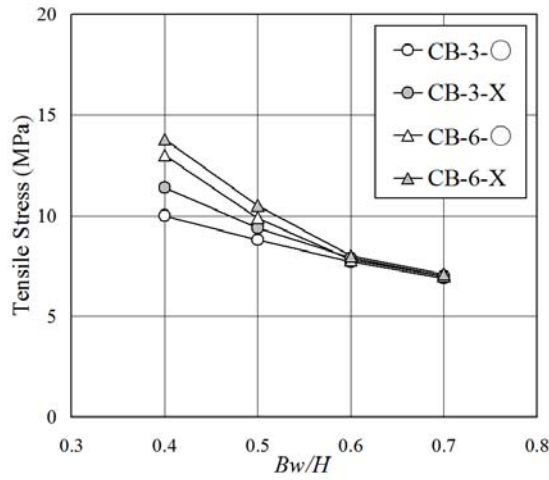
3.2 Stress Level

To evaluate stiffened efficiency of knee-brace as a stiffener, stress level of the knee-brace and the other members in steel box-girder bridge are computed by using numerical analyses and compared the analytical results according to parameter for installation of the knee-brace. Figure 6 shows stress level of members in steel box-girder bridge; cross-beam, diaphragm and web of steel box-girder.

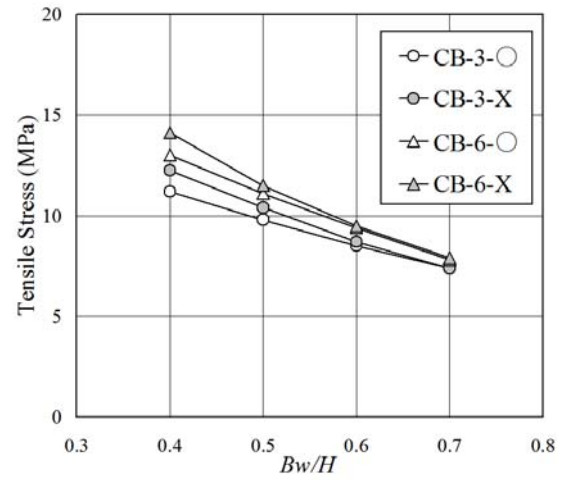
Figure 6(a), (b) show stress levels of web and lower flange of cross-beam, respectively. In those members, tensile stress distribution is dominant. Difference between the CB-O models (with knee-brace) and CB-X models (without knee-brace) is not exceeded about 3 MPa. In the case that B_w/H ratio is more than about 0.6, the difference is almost insignificant.

Figure 6(c), (d) show stress levels of diaphragm along B_w/H ratio. In case of CB-3 models (cross-beam length : 3m), distributions of effective and shear stress level are similar at all ranges of B_w/H regardless of installation of knee-brace. In case of CB-6 models (cross-beam length : 6m), stress level has a little difference, this magnitude is not exceeded about 5MPa.

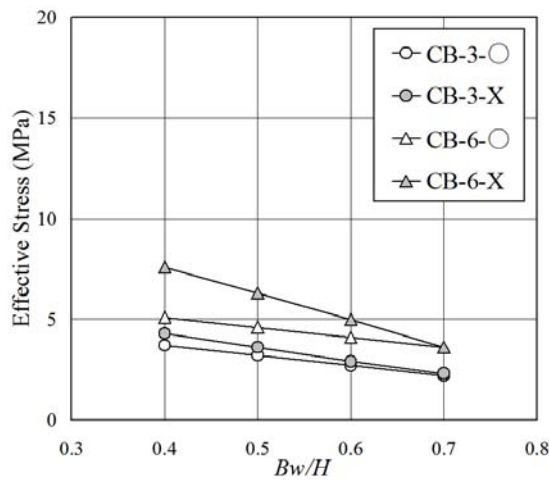
Figure 6(e), (f) show stress levels of joint side-web of steel box-girder along B_w/H ratio. In case of shear stress distribution, stress level is almost similar for all analysis models. In case of effective stress distribution, CB-3 models tend to similar distribution in all B_w/H ratio. A little difference is produced at CB-6 models, however, these magnitude is vary small, about less than 3MPa.



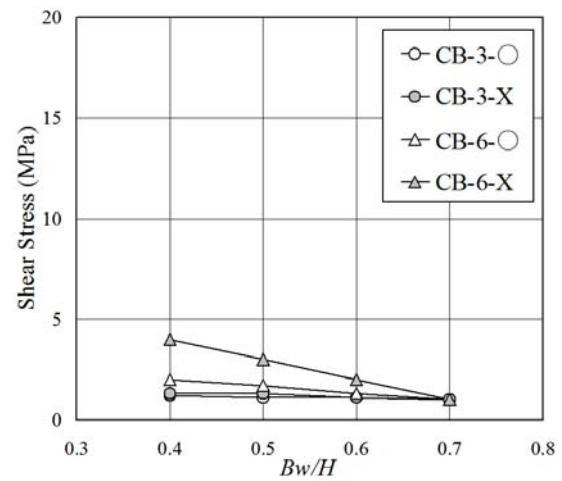
(a) Tensile stress in web of cross-beam



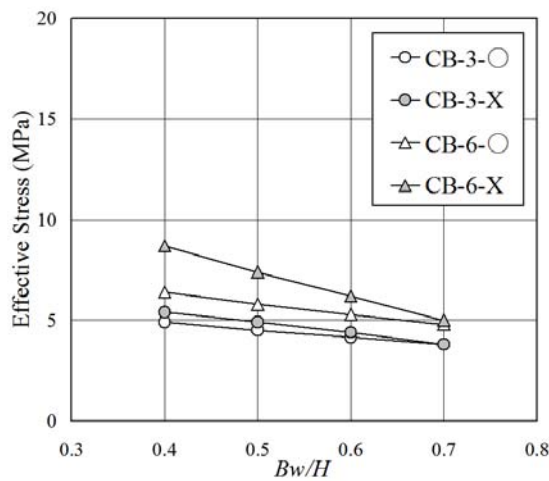
(b) tensile stress in lower flange of cross-beam



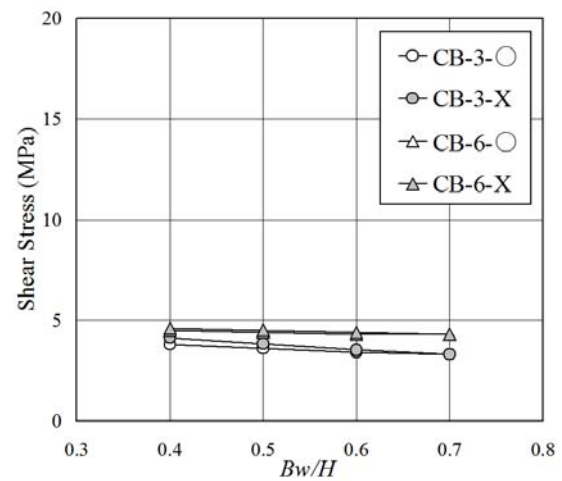
(c) Effective stress in diaphragm



(d) Shear stress in diaphragm



(e) Effective stress in web of steel box-girder



(f) Shear stress in web of steel box-girder

Figure 6. Stress level of members at steel box-girder bridge

To evaluate stiffened efficiency of knee-brace as a stiffener, stress level of the knee-brace and the other members in steel box-girder bridge are computed by using numerical analyses and compared the analytical results according to parameter for installation of the knee-brace. Figure 6 shows stress level of members in steel box-girder bridge; cross-beam, diaphragm and web of steel box-girder.

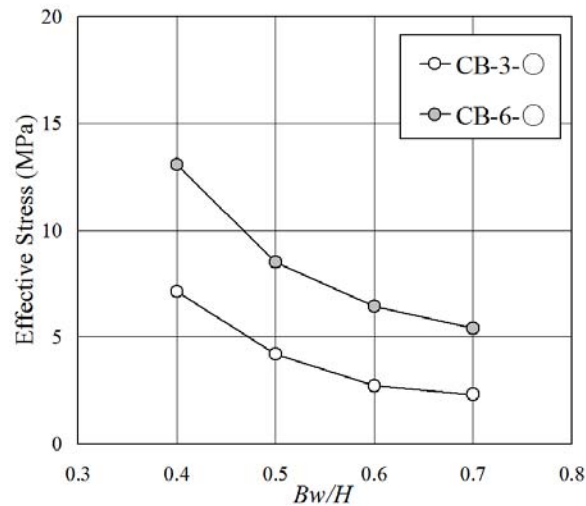


Figure 7. Effective stress level of knee-brace

Figure 7 shows distributions of effective stress along Bw/H ratio. Effective stresses of analysis models tend to decrease with increasing Bw/H ratio. Absolute magnitudes of effective stress are small, less than about 7MPa on the CB-3-O models and about 13MPa on the CB-6-O models, respectively. Figure 8 shows effective stress contour of CB-3-O-0.5 model. It is seen from figure 8 that stress distribution is concentrated at web of steel box-girder and cross-beam.

It is seen from analytical results of steel box-girder bridge members that differences of stress level are relatively small or almost similar regardless of installation of knee-brace. This tendency shows that the knee-brace of steel box-girder bridge is not efficiency as a structural stiffener to resist service load and relieve stress concentration of joint. Therefore, it is suffice to talk that the knee-brace can not be expected as the stiffener member to prevent lateral deformation and stress concentration, and to achieve rigid connection between the cross-beam and the steel box-girder.

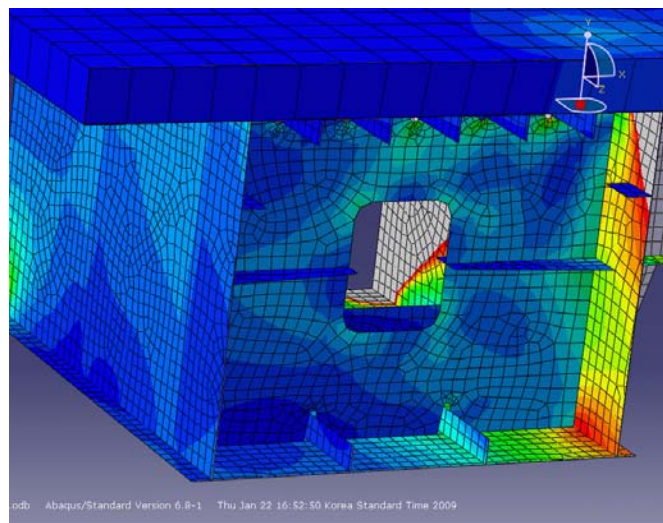


Figure 8. Effective stress contour

4. CONCLUDING REMARK

Stiffened efficiency of knee brace as a structural stiffener member is researched by using parametric FE analysis with installation of the knee-brace, depth ratio of cross-beam/box-girder(B_w/H), and cross-beam length. Stress flow and level of the knee brace as well as the web, the diaphragm and the cross beam are analyzed. It is concluded from analytical results of steel box-girder bridge members that differences of stress level between steel box-girder bridge with the knee brace and that without the knee brace are relatively small or almost similar regardless of installation of knee-brace. It is concluded from this tendency that the knee-brace of steel box-girder bridge is not efficiency as a structural stiffener and cannot be expected as the stiffener member to prevent lateral deformation and stress concentration at connection between the cross-beam and the steel box-girder.

REFERENCES

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